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An Analysis of Biomass Technology and its Impact on Multi-fuel Fired Biomass Boiler

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Abstract *:- **The availability of biomass in India is about 120-150 million MT per annum corresponding to potential of 16,000 MW. Multifuel fired biomass boiler design will enable latest technology up gradation in biomass and will have many advantages. This paper deals with technology analysis and multifuel fired biomass boiler design.***

Keywords-Biomass, Multi-fuel, biofuels, boiler, design

I. Introduction

Biomass is an important source of energy accounting for about one third of the total fuel used in our country and in about 90% of the rural households[i]. Biomass as the solar energy stored in chemical form in plant and animal materials is one of the most precious and most promising alternative fuels not only for power generation but also for other industrial and domestic applications. It provides not only food but also energy, building materials, paper, fabrics, medicines and chemicals. Biomass has been used for energy purposes ever since man discovered fire. If we burn biomass efficiently, oxygen from the atmosphere combines with the carbon in plants and produces more CO2 and water. The process is cyclic because the carbon dioxide is then available to produce new biomass product.

The widespread use of biomass is for household cooking and heating. The types of biomass used are agricultural waste, wood, charcoal or dried dung. Under its 11th Plan period (2007-2012), the government of India aimed to add 1,700 MW capacities through biomass and bagasse cogeneration in various states, including Maharashtra, Uttar Pradesh, Tamil Nadu and Karnataka [ii]. As per the National Biomass Resource Atlas prepared by the Indian Institute of Science, Bangalore, under a project sponsored by the Ministry, a cumulative biomass power potential of about 18,000 MWe from surplus agro-residues has been estimated in the country. The target consists of 500 MW from biomass projects and 1,200 MW from projects based on utilizing bagasse (the fibrous pulp byproduct of sugarcane processing) as a source of bioenergy. The total technical biomass potential from residues and energy crops in India is estimated to be around 66,880MW.

II. BIOMASS PRODUCTIVE TECHNOLOGIES

Technologies that enable efficient use of biomass are becoming prevalent in rural areas.
The efficiency of fuel usage is increased by

- use of improved designs of stoves which double the efficiency such as smokeless energy efficient chulhas
- compressing the biomass to form briquettes which not only occupy lesser space but also are more efficient
- conversion of organic matter into biogas through anaerobic digestion which apart from meeting fuel needs also gives digested manure for farms
- conversion of biomass into producer gas through partial combustion of biomass under controlled air supply

a) New BEKON Biogas technology

Till now, biogas technology mainly concentrated on the "wet fermentation" of agricultural and communal organic waste, while the recently patented BEKON dry fermentation process can produce methane from organic matter with a high content of dry matter. This kind of energy production is environmentally sound and economically interesting, while also creating and securing employment [i].

A great potential for energy generation from organic matter is found in agricultural by-products and wastes, communal organic waste and cuttings from coppicing and other maintenance work in the countryside and forests. With the dry fermentation process biogas with high energy content is produced that can then be converted into electricity and heat in block-type thermal power stations.

Instead of disposing of organic matter from agriculture or communal waste in other ways, dry fermentation offers a means of turning it into a valuable resource and extracting the highest possible benefit from it (in the form of biogas, electricity, heat, compost and fertilizer). The high quality compost, which results from the process of dry fermentation, can be used as a valuable fertilizer for agricultural and horticultural purposes [iii].

The BEKON dry fermentation process is a single-stage batch process for biogas generation from biomass with high dry matter content.

The organic matter is inoculated with substrate that has already been fermented. It is then filled into the digester and fermented under airtight conditions [iv]. Continual inoculation with bacterial matter occurs through recirculation of percolation liquid, which is sprayed over the organic matter in the digester. No stirring of the

organic matter is necessary during the dry fermentation process, as it is in conventional wet fermentation systems[v].

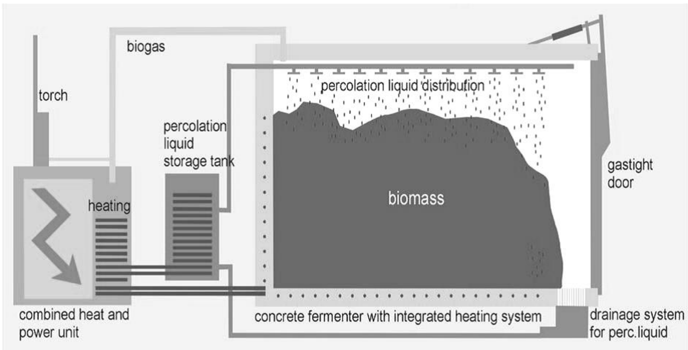

Fig no.1

The temperature of the process and of the percolation liquid are regulated by a built-in floor heating system in the digester and a heat exchanger in the tank which acts as a reservoir for the percolation liquid.

Technology for Heat and Power Generation

The biogas is dried in a gas-processing chamber, where gas quality and volume are measured. It is then pumped through a gas-regulating device, with the necessary safety installations, into a combined heat and power unit. An especially designed biogas gas engine in the co-generation unit generates electricity [vi]. Some of the excess heat is used to maintain optimum temperature in the digesters, but most is available for other uses [ii]. A further interesting development in the use of biogas will be its upgrading and adaptation to natural gas standards, so that it can be used in natural gas driven vehicles [vii]. Once the fermentation process is finished, the digesters are emptied and the digested matter, with a decomposition grade of 2-3, can either undergo further composting or be spread directly onto fields. The highly valuable compost can be utilized as a quality fertilizer by farmers, municipalities and in private and commercial gardening operations.

Biomass Energy and Cogeneration

The availability of biomass in India is estimated at about 540 million tons per year covering residues from agriculture, forestry, and plantations. Principal agricultural residues include rice husk, rice straw, bagasse, sugar cane tops and leaves, trash, groundnut shells, cotton stalks, mustard stalks, etc. It has been estimated that about 70- 75% of these wastes are used as fodder, as fuel for domestic cooking and for other economic purposes leaving behind 120- 150 million tons of usable agricultural residues per year which could be made available for power generation. By using these surplus agricultural residues, more than 16,000 MW of grid quality power can be generated with presently available technologies [vii]. In addition, about 5000 MW of power can be produced, if all the 550 sugar mills in the country switch over to modern techniques of co-generation. Thus, the country is considered to have a biomass power potential of about 21,000 MW.

b) Biomass-based Power Generation

- India produces a huge quantity of biomass material in its agricultural, agro-industrial, and forestry operations. According to some estimates, over 500 million tonnes of agricultural and agro-industrial residue alone is generated every year.
- This quantity, in terms of heat content, is equivalent to about 175 million tonnes of oil.
- A portion of these materials is used for fodder and fuel in the rural economy. However, studies have indicated that at least 150–200 million tonnes of this biomass material does not find much productive use, and can be made available for alternative uses at an economical cost.
- These materials include a variety of husks and straws. This quantity of biomass is sufficient to generate 15 000–25 000 MW of electrical power.
- In addition, electricity can also be generated from biomass grown on wastelands, road and rail track side plantations, etc. The quantum of electricity that can be produced from such biomass has been estimated to be in excess of 70 000 MW.
- Thus, the total electricity generation potential from biomass could reach a figure of about 100 000 MW.

c) Wood Gas Power Generation

Using wood gas, it possible to operate a diesel engine on dual fuel mode[viii]. Diesel substitution of the order of 80 to 85% can be obtained at nominal loads. The mechanical energy thus derived can be used either for energising a water pump set for irrigational purpose or for coupling with an alternator for electrical power generation, either for local consumption or for grid synchronisation. An appropriate site to realise the above application is an unelectrified village or hamlet. The benefits derived from this could be many, right from irrigation of fields to the supply of drinking water, and illuminating the village to supporting village industries. The other suitable sites could be saw mills and coffee plantations, where waste wood (of course of specified size) could be used as a feed stock in gasifiers.

d) Wood Gasifier

This system is meant for biomass having density in excess of 250 kg/m3. Theoretically, the ratio of air-to-fuel required for the complete combustion of the wood, defined as stoichiometric combustion is 6:1 to 6.5:1, with the end products being CO_2 and H_2O. Whereas, in gasification the combustion is carried at sub-stoichiometric conditions with air-to-fuel ratio being 1.5:1 to 1.8:1[ix].The product gas thus generated during the gasification process is combustible. This process is made possible in a device called gasified, in a limited supply of air. A gasifier system (Fig. 2) basically comprises of a reactor where the gas is generated, and is followed by a cooling and cleaning train which cools and cleans the gas[x]. The clean combustible gas is available for power generation in diesel-gen-set. Whereas, for thermal use the gas from the reactor can be directly fed to the combustor using an ejector. Biomass_based power plants can generate grid quality power. A wide variety of fuels like firewood, rice husk, coconut fronds, coconut shell and crop stalks etc. can be used. 1 MW grid connected biomass based power plant operating for 5000 hrs in a year would require about 6000T of dry wood (Approximately 1.3 kg of dry wood per kWh).

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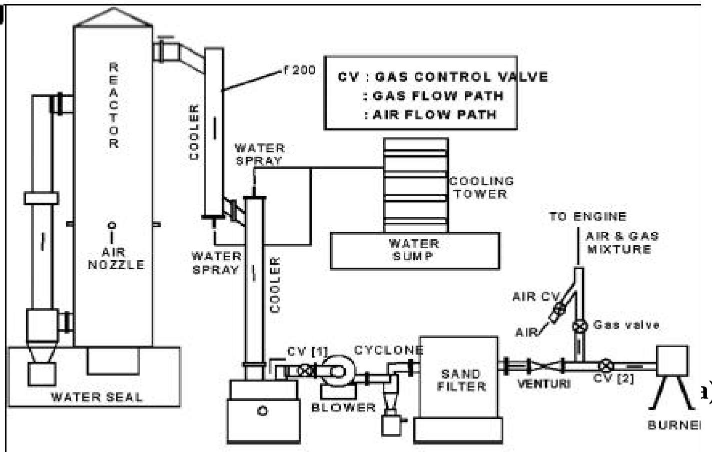

Fig. 2 SCHEMATIC OF WOOD GASIFIER FOR POWER GENERATION APPLICATION

III. Biomass Resources

Biomass resources are in the form of herbaceous energy, woody energy, industrial energy, agricultural crops, aquatic crops, agriculture crop residues, forestry residues, municipal waste, biomass processing residues, animal wastes etc.

IV. Biomass - Indian Scenario

Biomass contributes to about 14% of the total energy supply worldwide. India, being a tropical country, has tremendous potential for energy generation through biomass and its residues. Biomass energy is normally produced from firewood, agricultural residues such as bagasse, crop stalks, animal dung and wastes generated from agro-based industries. In India, biomass energy is being utilized mainly for domestic, commercial and industrial applications. Globally, India is in the fourth position in generating power through biomass and with a huge potential, is poised to become a world leader in utilization of biomass [ii]. Over 40 percent still lack access to electricity, 74 percent or rural India depend on biomass, and most of the growth in electricity consumption has served the upper and middle classes. MNRE estimate for 2032, includes 73,000 MW for Biomass (including Bagasse Cogeneration and Waste to Energy)

V. Biomass As A Form Of Energy

Biomass as A FUEL

Biomass in the form of organic waste can be (a) incinerated or (b)has to be processed further to produce a fuel and this is normally achieved through a number of methods including

1. Anaerobic Digestion
2. Gasification

These processes produce a biogas, generally methane, which is then burnt to produce energy. In many cases energy crops are also put through a gasification [ix] process and the subsequent biogas is then burnt in gas fired boilers to produce steam which in turn is used to produce electricity (steam turbines).

Incineration

It is the process of direct burning of biomass in the presence of excess air (oxygen) at temperatures of about 800°C and above, liberating heat energy, inert gases and ash. Controlled combustion of waste.

Combustion technologies available:

a. Unprocessed solid waste combustion technology (also known as mass burning)
b. Processed solid waste combustion technology (also known as RDF burning)

Merits

- Thermal Energy recovery for direct heating / power generation
- Relatively noiseless and odorless and Hygienic
- Low land area requirement
- Can be located within city limits, reducing cost of waste transportation.

Demerits

High capital and O & M Cost, ash disposal problem and least suitable for high moisture content are major demerits.

VI. Multi-Fuel Fired Biomass Boiler

Biomass characteristics: Different fuel play a important role for the selection of the multifuel firing characteristics inside the boiler. The characteristics of multi-fuel fired boiler will depend on the type of fuel used inside the gasifier which also leads to type of fuel gasifier selection in different arena. Biomass boilers are a favoured heating choice for The ease of installation, lower running costs (compared to oil and LPG) and reduced Carbon emissions. However, due to the varied maintenance requirements of different biomass, boiler manufacturers offer differing system designs [xi]. The boiler grate system should be suitable for wood pellet fuel [ii]. The boiler should provide an efficiency of >80%; the efficiency should be independently verified The boiler turn down range should accurately match the range of outputs likely to be experienced at each specific site (i.e. during winter and summer loads)[xii]. The characteristics of the fuel as shown in Tables 1 & 2 will play an important role for the design of boiler and selection of the boiler.

Three stage burn-back protection, including a drop cell with rotary valve, water dousing system and a flame detection or thermal cut-out device is essential for boiler located in or adjacent to occupied buildings[xiii]. Otherwise, a more basic two-stage protection system comprising a water dousing system and a sealed airtight fuel store may be acceptable for boiler located in a boiler house set some distance from occupied buildings. Biomass Fuel characteristics shows the different fuel properties along with the internal composition component.

TABLE-1 Biomass Characteristics

	Bagasse	**Paddy Straw**	**Rice Husk**	**Coconut Husk**	**Cotton Stalk**
Carbon	23.50	44.7	39.6	39.4	45.67
Hydrogen	3.40	3.94	4.45	4.86	3.85
Nitrogen	0.00	0.47	2.55	2.12	0.1
Ash	1.50	15.87	17.4	7.36	4.48
Moisture	50.00	5.52	3.6	13.33	13.89
Sulphur	0.05	0.96	0.1	0.08	0.16
Oxygen	21.55	28.54	32.3	32.85	31.85
GCV [Kcal/Kg]	2270	3400	3250	3602	3740

Automatic de-ashing is a necessity on all biomass boilers in order to reduce the amount of manual intervention required by the building staff; the emptying of the ash from the boiler will be carried out by the fuel delivery company only when fuel is delivered to the site, creating an irregular attendance pattern for de-ashing. A second/spare de-ashing bin should be provided for all sites so that, in the event that the ash bin becomes full prior to a fuel delivery/de-ashing visit, the property janitor/facilities manager can simply remove the full bin, setting it aside for

emptying by the fuel delivery contractor at a later date and replace it with the empty bin.

TABLE-2 Biomass Fuel Characteristics

	Bagasse	Paddy Straw	Rice Husk	Coconut Husk	Cotton Stalk
SiO_2	69.88	66.2	91.44	32.04	6.42
SO_3	0.08	2.91	0.4	-	7.8
CaO	4.75	4.15	1.42	17.25	26.64
MgO	2.83	3.65	-	22.73	1.84
Fe_2O_3	6.49	0.18	0.28	0.39	0.37
Al_2O_3	9.10	0.34	-	0.21	18.72
Na_2O	1.22	0.54	-	18.91	4.52
K_2O	2.79	18.88	4.3	2.94	23.21
$Ti\ O_2$	-	0.15	0.04	0.02	0.04
Cl	-	2.46	-	0.01	0.72
P_2O_5	2.01	0.54	-	-	4.23
Others	0.85	0.08	-	5.5	5.5
IDT	1150	700	1100	750	800

Fuel Store & Feed System: Fuel level within the biomass fuel store must be clearly seen via glass fuel level windows as well as the installation of an electronic fuel level warning system. Fuel store windows must be located as to give an accurate fuel level reading when viewed Consideration must be given to how the delivery fuel into the store will take place [ii]. This typically requires both vehicular access and a conventional way to transfer the fuel from the delivery lorry into the store.

Boiler Maintenance: Boiler maintenance is a huge cost issue excessive maintenance requirements i.e. monthly maintenance which requires a contractor attending site to carry out, is not an option. Maintenance costs must be kept to a minimum with an external contractor only being required to attend site on a yearly basis to carry out yearly maintenance. All other maintenance of the boiler must be able to be carried out by the building janitor or facilities manager with minimal training being required.

VII. Biomass In Rural Sector

Biogas technology provides an alternative source of energy in rural India for cooking. It is particularly useful for village households that have their own cattle. Through a simple process cattle dung is used to produce a gas, which serves as fuel for cooking [vi]. The residual dung is used as manure Biogas plants have been set up in many areas and are becoming very popular. Using local resources, namely cattle waste and other organic wastes, energy and manure are derived. A mini biogas digester has recently been designed and developed, and is being in-field tested for domestic lighting[x].

Uses of Plants: Generally the uses of the gas can be as under
1) Cooking
2) Lighting
3) Motive Power to run pump set
4) Can produce electricity.

Motive Power can be produced by linking the Gobar Gas to a dual fuel engine, specially designed for Gobar Gas.

Social benefits:
1) By saving on consumption of kerosene/gas, burden on exchequer (foreign exchange) is reduced.
2) Generation of Motive Power and running of pump set by the biogas reduces the dependence on electricity. The saved on electricity can be utilized for setting up Industrial units etc[xiv].
3) Organic manure help increase the fertility of the soil and also the crop output.
4) The other benefit is arresting deforestation/stopping of felling of trees as consumption of wood as fuel is reduced.

Biogas Generation:
- Biogas Produced from organic materials such as animal dung, canteen wastes, industrial wastes and selective plants could be used in biogas plants[ii]. The gas essentially comprises of methane and CO2 in the ratio 55:45. It is the methane which has the fuel value.
- It is estimated that about 100 metric tons of cattle dung would be required to generate 300 kW of power.

Energy security: Domestic biomass energy could help our nation to substantially reduce dependence on fossil fuels. Rural economic growth: Biomass energy could stimulate growth in farming, forestry and rural industry leading to overall rural development. Biomass energy could also provide a productive avenue for using agricultural and forestry wastes, besides plantations[xv].

VIII. Decentralised Distribution Generation (DDG) With Different Biomass Technology

Decentralized Distribution Generation or Decentralized Energy Generation means “Points of generation of energy being close to points of end-use of that energy.” Decentralized Distribution Generation (DDG) is the integrated or stand-alone use of small, modular electricity generation sources installed within the distribution system or at a customer’s site by utilities, utility customers and other third parties to meet specific capacity and reliability needs in applications that benefit the electricity system, specific end-use customers, or both.

Advantages of DDG
- Transmission and distribution loss is minimized.
- The generation and transmission cost is less.

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IX. Benefits From Biomass & Environment Impacts

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avenue for using agricultural and forestry wastes, besides plantations[xiii].

Environmental protection: By offsetting fossil fuel use and related emissions of nitrogen oxides, sulphur dioxides, and other pollutants, biomass energy will contribute to cleaner air and water[xii]. Furthermore, increased cultivation of carbon-fixing plants will help mitigate green house gas emissions that contribute to global climate change.

X. Conclusion

The heat and power segments together represent approximately 10,000 TWh per year. The development of the new technology in the biomass and modern up gradation leads to modern design of boiler. The development of biomass boiler design in the relevant of gasification and provide modern combustion and leads to use the woodgas and gasification modern techniques in the rural and modern area. There are three main opportunities to increase biomass as a way to generate heat and power[xvi]. Co-firing or conversion of existing assets, where an existing hard coal or lignite plant that generates heat and/or electricity is modified to accept a percentage of biomass in the fuel mix (co-firing), or partly re-built to accept up to 100 percent biomass (conversion). One major application area for biomass is co-firing in existing coal-fired power and/or heat plants. The exact percentage of co-firing that is possible depends on what alterations companies are willing to undertake, and what efficiency losses they are willing to accept, and it also varies from plant to plant. Besides this multifuel fired biomass boiler offers a reduction in operation & maintenance cost and more plant availability due to versatility in fuel feed & availability of fuel for most part of the year. Biomass can be a good source for viable rural electrification by decentralized distributed generation systems.

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